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Jurich et al.

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(54) **TRACKING MOVEMENT OF AN EYE WITHIN A TRACKING RANGE**

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(51) **Int. Cl.**

A61B 3/113	(2006.01)
A61B 3/00	(2006.01)
A61F 9/008	(2006.01)

(52) **U.S. Cl.**

CPC ***A61B 3/113*** (2013.01); ***A61B 3/0025*** (2013.01); ***A61F 9/008*** (2013.01); *A61F 2009/00846* (2013.01); *A61F 2009/00897* (2013.01)

(58) **Field of Classification Search**

CPC A61B 3/113; A61B 3/0025; A61F 9/008

USPC 351/205, 209

See application file for complete search history.

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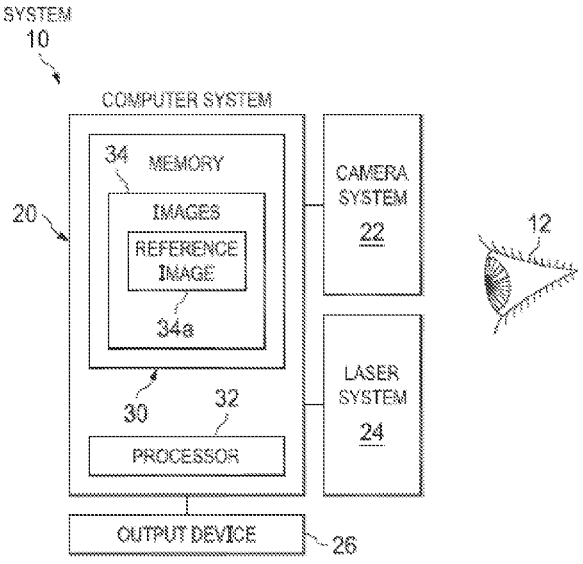
Primary Examiner — James R Greece

(57) **ABSTRACT**

In certain embodiments, a system for tracking movement of an eye comprises a camera system, a computer system, and an output device. The camera system generates images of the eye. The computer system stores the images and at least one of the images as a reference image. The computer system also tracks movement of the eye within a tracking range by comparing a current image with the reference image, and by determining a movement of the eye from the comparison of the current image and the reference image. The tracking range has one or more alert points. The computer system also determines an orientation of the eye relative to at least one alert point of the tracking range. The output device outputs a range indicator that indicates the orientation of the eye relative to the at least one alert point of the tracking range.

19 Claims, 5 Drawing Sheets



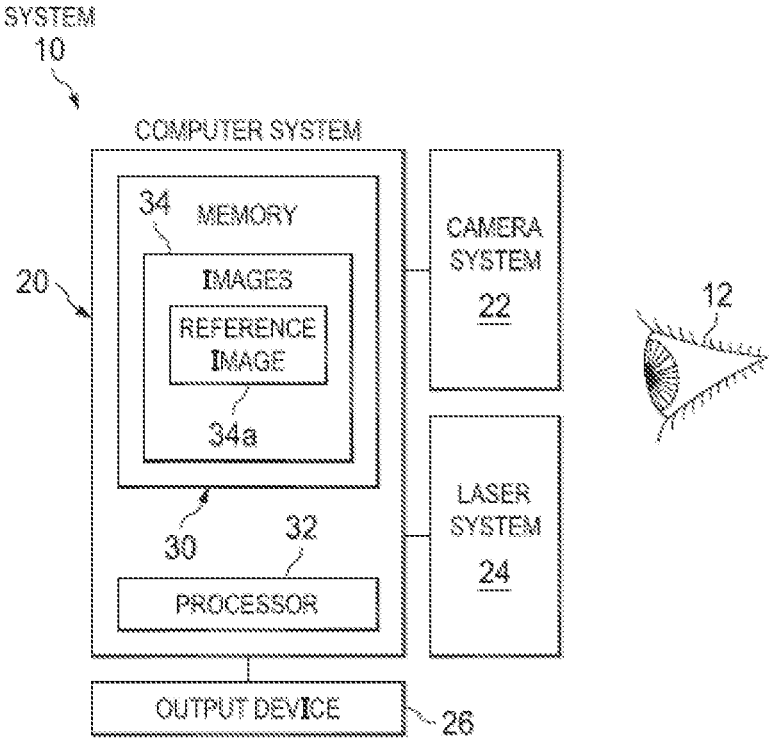


FIG. 1

Fig. 3A

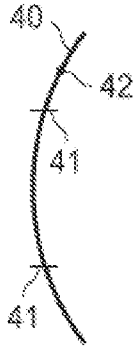


Fig. 3B

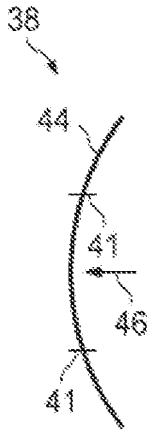


Fig. 4A

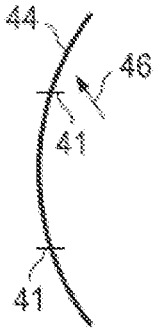


Fig. 4B

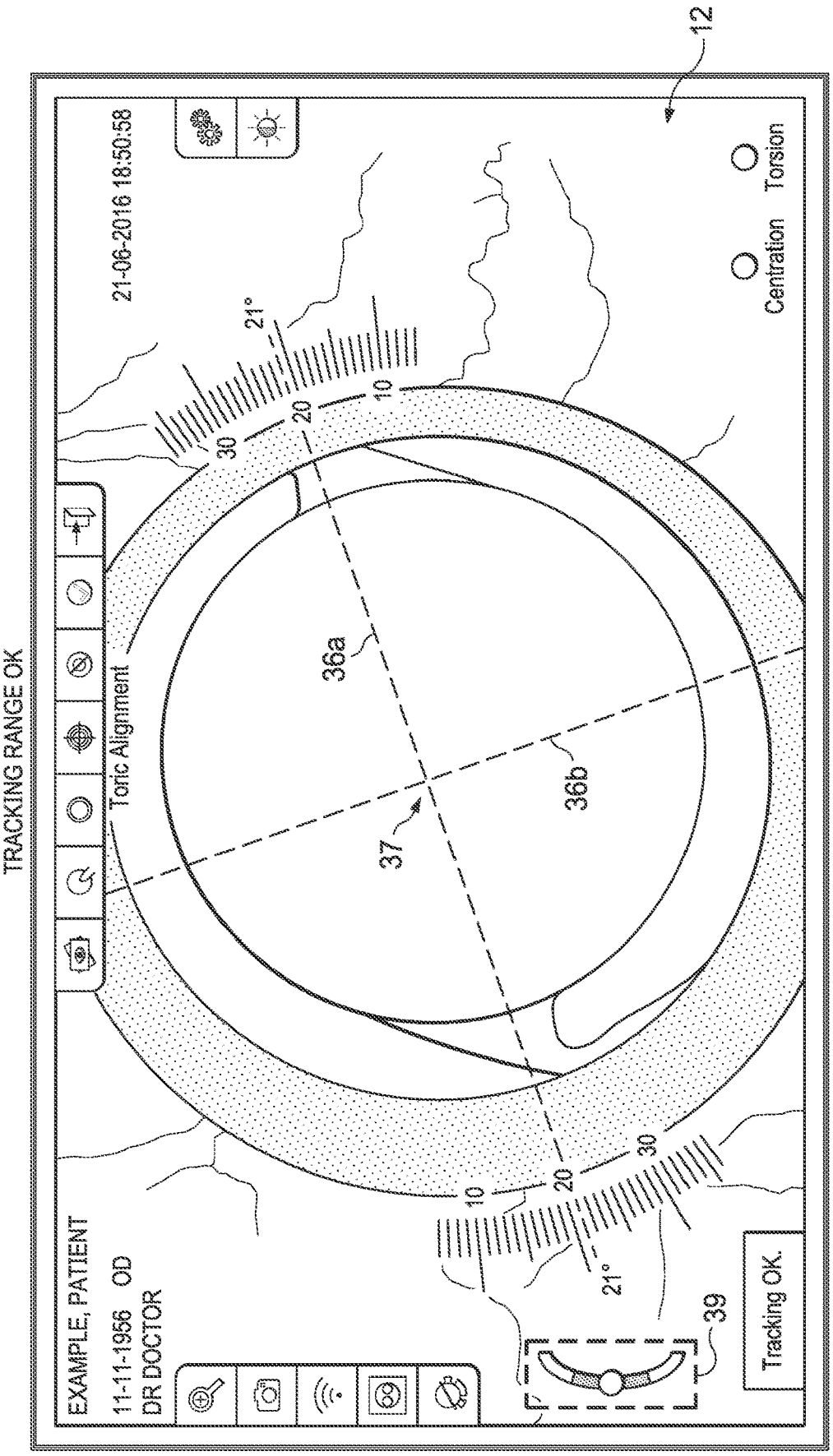

12
TRACKING RANGE OK
21-06-2016 18:50:58
Toric Alignment
Centration
Torsion
EXAMPLE, PATIENT
11-11-1956 OD
DR DOCTOR
36a
36b
37
39
21°
10
20
30
Tracking OK.

FIG. 2A

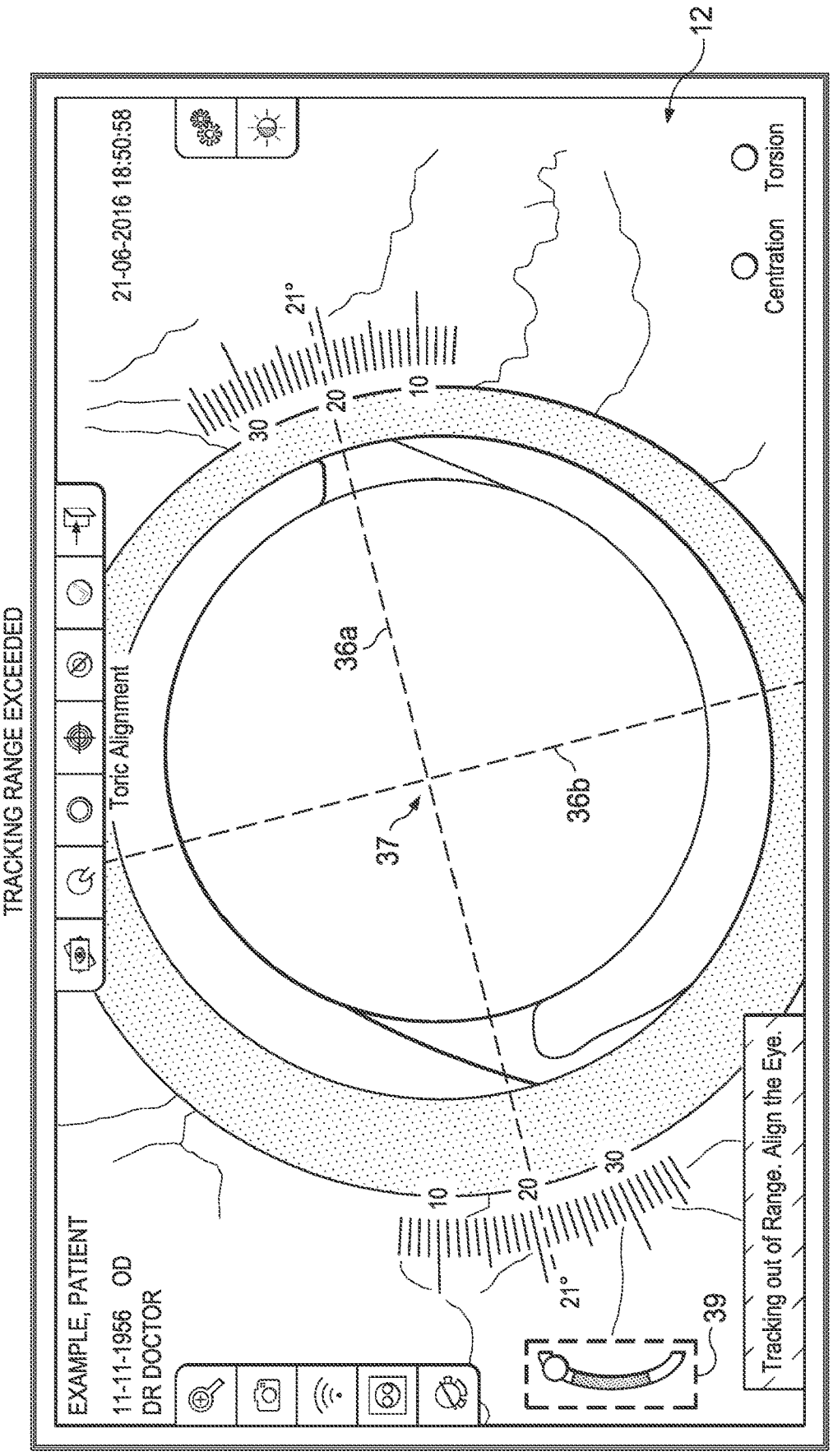

12
TRACKING RANGE EXCEEDED
EXAMPLE, PATIENT
11-11-1956 OD
DR DOCTOR
21-06-2016 18:50:58
Toric Alignment
Centration
Torsion
21°
30
20
10
36a
36b
37
39
Tracking out of Range. Align the Eye.

FIG. 2B

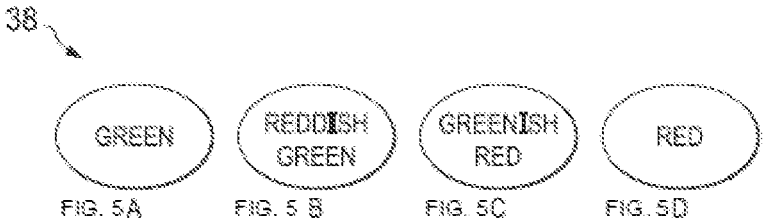


FIG. 5A FIG. 5B FIG. 5C FIG. 5D

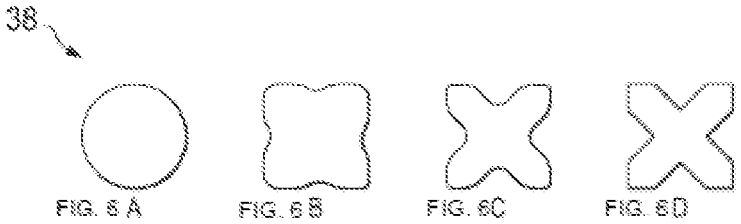


FIG. 6A FIG. 6B FIG. 6C FIG. 6D

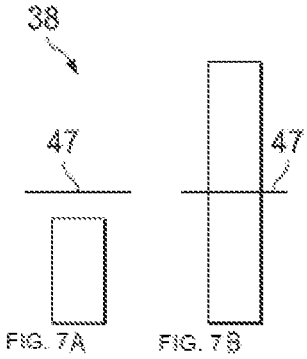


FIG. 7A FIG. 7B

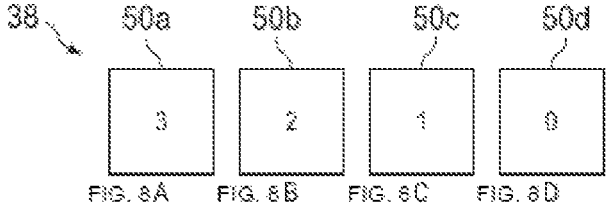


FIG. 8A FIG. 8B FIG. 8C FIG. 8D

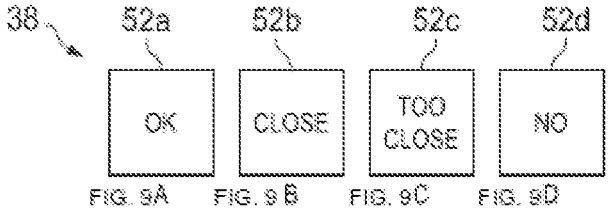


FIG. 9A FIG. 9B FIG. 9C FIG. 9D

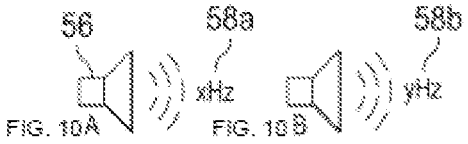


FIG. 10A FIG. 10B

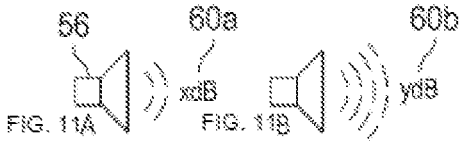


FIG. 11A FIG. 11B

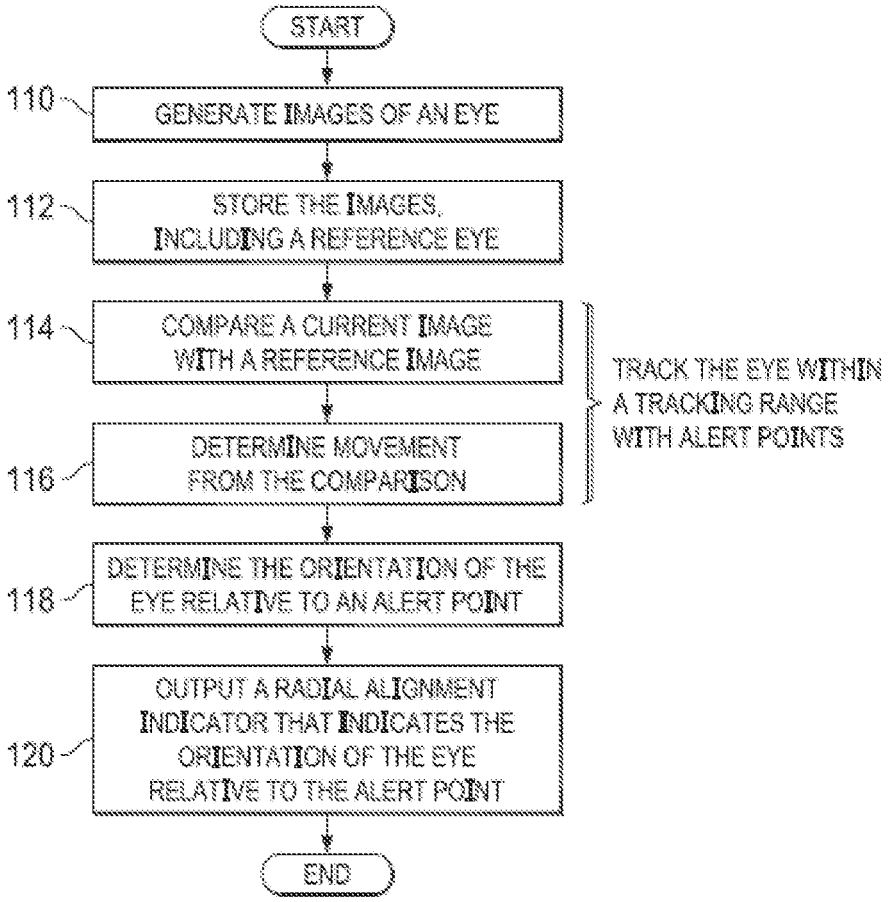


FIG. 12

TRACKING MOVEMENT OF AN EYE WITHIN A TRACKING RANGE

TECHNICAL FIELD

The present disclosure relates generally to eye-tracking, and more specifically to tracking movement of an eye within a tracking range.

BACKGROUND

Image guided systems have been developed for use with ophthalmic surgical devices, such as cataract refractive and LASIK surgical devices. The systems create a digital image of the patient's eye that capture features of the eye, e.g., scleral vessels, limbus, and iris features. This image is used to, e.g., position incisions and lens alignment in real time. The systems may have eye-tracking capabilities that detect translational and rotational movement of the eye. In some systems, eye-tracking helps keep the laser beam on target during surgery. Studies have shown that eye-tracking produces better outcomes and decreases complications.

BRIEF SUMMARY

In certain embodiments, a system for tracking movement of an eye comprises a camera system, a computer system, and an output device. The camera system generates images of the eye. The computer system comprises a memory and one or more processors. The memory stores the images and at least one of the images as a reference image. The processors track movement of the eye within a tracking range by comparing a current image of the plurality of images with the reference image, and by determining a movement of the eye from the comparison of the current image and the reference image. The tracking range has one or more alert points. The processors also determine an orientation of the eye relative to at least one alert point of the tracking range. The output device outputs a range indicator that indicates the orientation of the eye relative to the at least one alert point of the tracking range.

In certain embodiments, a method for tracking the movement of an eye comprises generating images of the eye. The images are stored and at least one of the images is stored as a reference image. Movement of the eye is tracked within a tracking range by comparing a current image of the plurality of images with the reference image, and by determining a movement of the eye from the comparison of the current image and the reference image. The tracking range has one or more alert points. An orientation of the eye is determined relative to at least one alert point of the tracking range. A range indicator that indicates the orientation of the eye relative to the at least one alert point of the tracking range is output.

BRIEF DESCRIPTION OF THE DRAWINGS

Embodiments of the present disclosure are described by way of example in greater detail with reference to the attached figures, in which:

FIG. **1** illustrates one embodiment of a system for tracking the movement of an eye during laser treatment surgery;

FIGS. **2**A and **2**B illustrate examples of range indicators during different tracking sessions;

FIGS. **3**A and **3**B illustrate an example of a graphical element with a slider element;

FIGS. **4**A and **4**B illustrate an example of a graphical element with an arrow element;

FIGS. **5**A to **5**D illustrate an example of a graphical element that changes color;

FIGS. **6**A to **6**D illustrate an example of a graphical element that changes shape;

FIGS. **7**A and **7**B illustrate an example of a graphical element that changes size;

FIGS. **8**A to **8**D illustrate an example of a graphical element that displays numbers;

FIGS. **9**A to **9**D illustrate an example of a graphical element that displays words;

FIGS. **10**A and **10**B illustrate an example of a sound that changes in frequency;

FIGS. **11**A and **11**B illustrate an example of a sound that changes in volume; and

FIG. **12** illustrates an example of a method for tracking the movement of an eye that may be performed by system of FIG. **1**.

DESCRIPTION OF EXAMPLE EMBODIMENTS

Referring now to the description and drawings, example embodiments of the disclosed apparatuses, systems, and methods are shown in detail. As apparent to a person of ordinary skill in the field, the disclosed embodiments are exemplary and not exhaustive of all possible embodiments.

FIG. **1** illustrates one embodiment of a system **10** for tracking the movement of an eye **12**, e.g., during a surgical or diagnostic procedure. System **10** provides a range indicator that indicates the orientation of eye **12** relative to an alert point of the eye tracking range, so a user can determine if eye **12** is close to moving outside of the tracking range before it actually does. This can be used to avoid some undesirable effects of moving outside of the tracking range. For example, in some systems, if the tracking range is exceeded, the system suspends tracking, which prolongs surgery time. As another example, the system may report false positive tracking if the tracking range is exceeded.

In the illustrated embodiment, system **10** comprises a computer system **20**, a camera system **22**, a laser system **24**, and an output device **26**. Computer system **20** includes one or more memories **30** and one or more processors **32**. In certain embodiments, camera system **22** generates images **34** of eye **12**. Computer system **20** controls eye tracking and laser control. Memory **30** stores images **34**, where at least one image **34** is stored as a reference image **34***a*. Processor **32** tracks eye **12** within a tracking range by comparing a current image **34** with reference image **34***a* and determining movement of eye **12** (e.g., change in location and/or angular orientation) from the comparison of current image **34** and reference image **34***a*. The tracking range has one or more alert points near or at the end of the tracking range of system **10**. Processor **32** determines the orientation of eye **12** relative to an alert point. Output device **26** outputs a range indicator that indicates the orientation of eye **12** relative to the alert point of the tracking range.

Camera system **22** may be any suitable system with detectors that can detect light reflected from eye **12** and generate a signal that can be used to create images **34** of eye **12**. An example of camera system **22** is a CCD camera. A sequence of images **34** of eye **12** ($i_1, \ldots, i_k, \ldots, i_n$) can show the movement of eye **12**. An image **34** is used as a reference image to compare to a current image from camera **22** to detect movement. The reference image may any suitable image i_{k-q}, $q \geq 1$ before the current image i_k, e.g., the immediate previous image i_{k-1} before the current image i_k.

Eye **12** has a location and orientation (or angular orientation or angular position), which may be described as the configuration of eye **12**. In certain embodiments, the location of eye **12** may be expressed using (x, y, z) coordinates the coordinate system used in ophthalmological surgery, where an eye feature such as an iris defines an xy-plane, and the z-axis is the line normal to the plane an passing through a central point of eye **12**. For example, the location of eye **12** on the xy-plane at time t may be given by (x(t), y(t)) coordinates of a central point of eye **12** (e.g., substantially about the pupil center or apex). The orientation, or angular position, of eye **12** may be expressed as rotation about a point of eye **12**, which may be a central point of eye **12**. For example, the orientation of eye **12** at time t may be given as an amount a(t) of degrees rotation away from a zero position at time t. The amount of degrees may be expressed with respect to one, two, or three axes, e.g.: a number $a_1(t)$ of degrees rotation about an axis A_1; a number $a_1(t)$ of degrees rotation about an axis A_1 and a number $a_2(t)$ of degrees rotation about an axis A_2; or a number $a_1(t)$ of degrees rotation about an axis A_1, a number $a_2(t)$ of degrees rotation about an axis A_2, and a number $a_3(t)$ of degrees rotation about an axis A_3. A zero position may be an initial angular position, such as the angular position of eye **12** when tracking starts at the beginning of a tracking session. A tracking session may start, e.g., at the initialization of tracking or at a restarting of tracking after, e.g., eye **12** has moved out of the tracking range.

Computer system **20** tracks the movement of eye **12** by determining a change in the configuration of eye **12**, such as the translational and/or angular (or rotational) movement of eye **12**. Translational movement is movement of all points of eye **12** by substantially the same amount in substantially the same direction. Angular movement is movement of points of eye **12** about a central point of eye **12**. In certain embodiments, system **20** may use image processing to locate the central point of eye **12**, e.g., the pupil, in the reference and current images **34** to determine translational movement and then translationally align the images **34** using the central point. System **20** may use image processing to locate features of eye **12** (e.g., blood vessels, iris features, or any other appropriate feature) to determine angular movement and then rotationally align the images **34** about the central point.

FIG. **2**A illustrates an example of showing the orientation (or angular position) of eye **12**. One or more lines **36** may indicate the position of eye **12**. In the illustrated example, lines **36***a*-b function as axes. Lines **36***a-b* pass substantially through a central point **37** of pupil of eye **12** and are substantially perpendicular to each other.

Referring back to FIG. **1**, in some embodiments, system **10** tracks the movement of eye **12** to be able to align an overlay image of eye **12** over images **34** of eye **12** generated by camera system **22**. Examples of an overlay image include a diagnostic image, an image of a treatment plan, an infrared image, or other image of eye **12**. The overlay image may be placed over or blended with image **34** generated by camera system **22**. When eye **12** moves in images **34**, system **10** adjusts the overlay image to compensate for the movement.

Computer system **20** can track the movement of eye **12** within a certain tracking range where tracking can be properly performed, e.g., performed with suitable accuracy and/or precision. Outside of the range, system **10** system may suspend tracking or may report false positive tracking. The tracking range may be expressed as P+/−Q, where P represents a zero position when tracking starts and Q represents the tracking boundary, which is maximum distance away from the zero position P at which tracking can be properly performed. The tracking range may have one or more alert points. An alert point S is a point at which system **20** provides a notification eye **12** is close to or at the tracking boundary, so S≤Q.

For tracking angular movement, the tracking range may be expressed as P+/−Q°, where P represents zero rotation when tracking starts and Q represents the tracking boundary. The tracking boundary Q is the maximum amount of degrees away from the zero rotation P at which tracking can be properly performed. Q may have any suitable value. For current systems, Q is in the range of 10 to 15 degrees, such as 15 degrees. As systems improve, Q may be in the range of 15 to 20, 20 to 25, 25 to 30 or greater than 30 degrees. Alert point S may have any suitable value, and may be selected based on Q. For example, S=Q or S=Q−T, where T in the range of 1 to 5, 5 to 10, 10 to 15, 15 to 20 or greater than 20 degrees, such as S=Q−T=15−5 degrees. Alert point S may be set by system **10**, or may be set by user through user input.

As computer system **20** tracks the movement of eye **12**, system **20** also determines the configuration of eye **12** relative to an alert point. For example, system **20** determines the orientation a(t) of eye **12** relative to an alert point S. The relationship may be expressed as a difference between the orientation of eye **12** and the alert point, e.g., a(t)−S. As eye **12** moves closer to the alert point S, the difference approaches zero.

Output device **26** outputs a range indicator that indicates the configuration (e.g., orientation and/or location) of eye **12** relative to the alert point S of the tracking range. Output device **26** may be any suitable device that provides computer output to a user or another computer, e.g., a display, monitor, projector, speaker, headphone, or printer. In certain embodiments, output device **26** is a display that shows the range indicator as a graphical element. A graphical element is a visual mark of any suitable size, shape, or color that typically conveys information. Examples of graphical element range indicators are described with reference to FIGS. **2**A to **9**B. In certain embodiments, output device **26** is a speaker that emits the range indicator as a sound. Examples of audio range indicators are described with reference to FIGS. **10**A to **11**B.

Referring to FIGS. **2**A and **2**B, range indicator **39** indicates the orientation of eye **12** during different tracking sessions. In FIG. **2**A, the zero point of the tracking session is P_1, so the tracking range of the session is P_1+/−Q. In FIG. **2**B, the zero point of the tracking session is P_2, so the tracking range of the session is P_2+/−Q. In FIG. **2**A, range indicator **39** indicates the orientation of eye **12** is within the tracking range. In FIG. **2**B, range indicator **39** indicates the orientation of eye **12** is outside of the tracking range. Note the orientation of eye **12** appears to be the same in both FIGS. **2**A and **2**B, even though eye **12** of FIG. **2**A is within the tracking range and eye **12** of FIG. **2**B is not. This is because FIGS. **2**A and **2**B describe different tracking sessions, and the determination of whether eye **12** is within the tracking range P+/−Q depends on the zero point P of the tracking session.

Referring back to FIG. **1**, laser system **24** receives a notification of the movement of eye **12**, and changes a laser beam position in response to the notification. Laser system **24** may be any suitable laser surgical device that provides a laser beam to treat eye **12**, and may comprise a computer, laser source, and scanning device. In certain embodiments, the scanning device receives the notification of the movement of eye **12** and modifies the focus of the laser beam to address or compensate for the movement. In this manner,

eye movements can be taken into account either for registration or for tracking purposes.

FIGS. **3**A and **3**B illustrate an example of a graphical element **38** with a slider element **42**. In the example, graphical element **38** includes a linear element **40** and a slider element **42**. Linear element **40** is a long, narrow mark that can be straight or curved. In the example, linear element **40** represents the tracking range and has at least one alert point element **41** representing an alert point of the tracking range. Slider element **42** is a mark along linear element **40**. In the example, slider element **42** represents the rotation of eye **12**. The position of the slider element **42** relative to point **41** represents the rotation of eye **12** relative to the alert point of the tracking range. FIG. **3**A shows the rotation of eye **12** not exceeding an alert point, i.e., is within an acceptable range. FIG. **3**B shows the rotation eye **12** exceeding an alert point, i.e., is outside of an acceptable range.

FIGS. **4**A and **4**B illustrate an example of a graphical element **38** with an arrow element **46**. In the example, graphical element **38** includes a linear element **44** and an arrow element **46**. Linear element **44** is similar to linear element **40**. In the example, linear element **44** represents the tracking range and has at least one alert point element **41** representing an alert point of the tracking range. Arrow element **46** is a mark that indicates a position along linear element **44**. In some cases, arrow element **46** may look like as illustrated or may look like a compass needle. In the example, arrow element **46** points to a point of linear element **44** that represents the rotation of eye **12**. The position where arrow element **46** points relative to point **41** represents the rotation of eye **12** relative to the alert point of the tracking range. FIG. **4**A shows the rotation of eye **12** not exceeding an alert point, i.e., is within an acceptable range. FIG. **4**B shows the rotation eye **12** exceeding an alert point, i.e., is outside of an acceptable range.

FIGS. **5**A to **5**D illustrate an example of a graphical element **38** that changes color. In certain embodiments, graphical element **38** changes continuously from a first color to a second color to indicate a change in the orientation of the eye relative to an alert point of the tracking range. The continuous color change may be changes in shade from the first color to the second color. In the illustrated example, FIG. **5**A shows a green graphical element **38**, indicating the rotation of eye **12** is not close to an alert point, i.e., is within an acceptable range. FIG. **5**B shows a reddish green graphical element **38**, indicating the rotation of eye **12** is approaching the alert point. FIG. **5**C shows a greenish red graphical element **38**, indicating the rotation of eye **12** is even closer to the alert point. FIG. **5**D shows a red graphical element **38**, indicating the rotation of eye **12** has exceeded the alert point, i.e., is outside of the acceptable range.

FIGS. **6**A to **6**D illustrate an example of a graphical element **38** that changes shape. In certain embodiments, graphical element **38** changes continuously from a first shape to a second shape to indicate a change in the orientation of the eye relative to an alert point of the tracking range. The continuous change in shape may be gradual changes from the first shape to the second shape. In the illustrated example, FIG. **6**A shows graphical element **38** as a circle, indicating the rotation of eye **12** is not close to an alert point, i.e., is within an acceptable range. FIG. **6**B shows graphical element **38** as a square with rounded corners, indicating the rotation of eye **12** is approaching the alert point. FIG. **6**C shows graphical element **38** as an X with rounded corners, indicating the rotation of eye **12** is even closer to the alert point. FIG. **6**D shows graphical element **38** as an X with sharp corners, indicating the rotation of eye **12** has exceeded the alert point, i.e., is outside of the acceptable range.

FIGS. **7**A and **7**B illustrate an example of a graphical element **38** that changes size. In certain embodiments, graphical element **38** changes continuously from a first size to a second size to indicate a change in the orientation of the eye relative to an alert point of the tracking range. An alert point mark **47** represents the alert point. In the illustrated example, FIG. **7**A shows graphical element **38** as a bar that does not cross mark **47**, indicating the rotation of eye **12** does not exceed an alert point, i.e., is within an acceptable range. FIG. **7**B shows graphical element **38** as a bar that crosses mark **47**, indicating the rotation of eye **12** exceeds an alert point, i.e., is outside of an acceptable range.

FIGS. **8**A to **8**D illustrate an example of a graphical element **38** that displays numbers. In certain embodiments, graphical element **38** displays a first number **50** that continuously changes to subsequent numbers **50** to indicate a change in the orientation of the eye relative to an alert point of the tracking range. In the illustrated example, FIG. **8**A shows graphical element **38** displaying "3", indicating the rotation of eye **12** is not close to an alert point, i.e., is within an acceptable range. FIG. **8**B shows graphical element **38** displaying "2", indicating the rotation of eye **12** is approaching the alert point. FIG. **8**C shows graphical element **38** displaying "1", indicating the rotation of eye **12** is even closer to the alert point. FIG. **8**D shows graphical element **38** displaying "0", indicating the rotation of eye **12** has exceeded the alert point, i.e., is outside of the acceptable range.

FIGS. **9**A to **9**D illustrate an example of a graphical element **38** that displays words. In certain embodiments, graphical element **38** displays a first word **52** that continuously changes to subsequent words **52** to indicate a change in the orientation of the eye relative to an alert point of the tracking range. In the illustrated example, FIG. **9**A shows graphical element **38** displaying "OK", indicating the rotation of eye **12** is not close to an alert point, i.e., is within an acceptable range. FIG. **9**B shows graphical element **38** displaying "CLOSE", indicating the rotation of eye **12** is approaching the alert point. FIG. **9**C shows graphical element **38** displaying "TOO CLOSE", indicating the rotation of eye **12** is even closer to the alert point. FIG. **9**D shows graphical element **38** displaying "NO", indicating the rotation of eye **12** has exceeded the alert point, i.e., is outside of the acceptable range.

FIGS. **10**A and **10**B illustrate an example of a sound that changes in frequency. In certain embodiments, a speaker **56** emits a sound that continuously changes in frequency **58** to indicate a change in the orientation of the eye relative to an alert point of the tracking range. In the example, FIG. **10**A shows a sound with a frequency **58***a* of x Hz indicating the rotation of eye **12** is not close to an alert point, i.e., is within an acceptable range. FIG. **10**B shows a sound with a frequency **58***b* of y Hz indicating the rotation of eye **12** exceeds an alert point, i.e., is outside of an acceptable range. Frequency y can be greater or less than frequency x, but not the same as frequency x.

FIGS. **11**A and **11**B illustrate an example of a sound that changes in volume **60**. In certain embodiments, a speaker **56** emits a sound that continuously changes in volume **60** to indicate a change in the orientation of the eye relative to an alert point of the tracking range. In the example, FIG. **11**A shows a sound with a volume **60***a* of x dB indicating the rotation of eye **12** is not close to an alert point, i.e., is within an acceptable range. FIG. **11**B shows a sound with a volume

60*b* of y dB indicating the rotation of eye **12** exceeds an alert point, i.e., is outside of an acceptable range. Volume y can be greater or less than volume x, but not the same as volume x.

In certain cases, a speaker **56** emits words to indicate a change in the orientation of the eye relative to an alert point of the tracking range. Any suitable words may be used, e.g., the words described relative to FIGS. **9**A and **9**B. Other examples of words include "rotate clockwise" if the tracking should be rotated clockwise to avoid exceeding the tracking range, or "rotate counter-clockwise" if the tracking should be rotated counter-clockwise to avoid exceeding the tracking range.

FIG. **12** illustrates an example of a method for tracking the movement of an eye that may be performed by system **10** of FIG. **1**. In the example, the method starts at step **110**, where images of the eye are generated. At step **112**, the images are stored, and at least one image is stored as a reference image. Steps **114** and **116** describe tracking eye **12** within a tracking range with one or more alert points. Eye **12** is tracked at step **114** by comparing a current image of the plurality of images with the reference image. Movement of eye **12** is determined from the comparison of the current image and the reference image at step **116**. The orientation of the eye is determined relative to an alert point of the tracking range at step **118**. A range indicator that indicates the orientation of the eye relative to the alert point of the tracking range is output at step **120**.

A component (e.g., a computer) of the systems and apparatuses disclosed herein may include an interface, logic, and/or memory, any of which may include hardware and/or software. An interface can receive input to the component, provide output from the component, and/or process the input and/or output. Logic can perform the operations of the component, e.g., execute instructions to generate output from input. Logic may be a processor, such as one or more computers or one or more microprocessors. Logic may be computer-executable instructions encoded in memory that can be executed by a computer, such as a computer program or software. A memory can store information and may comprise one or more tangible, non-transitory, computer-readable, computer-executable storage media. Examples of memory include computer memory (e.g., Random Access Memory (RAM) or Read Only Memory (ROM)), mass storage media (e.g., a hard disk), removable storage media (e.g., a Compact Disk (CD) or a Digital Video Disk (DVD)), and network storage (e.g., a server or database).

Although this disclosure has been described in terms of certain embodiments, modifications (such as substitutions, additions, alterations, or omissions) of the embodiments will be apparent to those skilled in the art. Accordingly, modifications may be made to the embodiments without departing from the scope of the invention. For example, modifications may be made to the systems and apparatuses disclosed herein. The components of the systems and apparatuses may be integrated or separated, and the operations of the systems and apparatuses may be performed by more, fewer, or other components. As another example, modifications may be made to the methods disclosed herein. The methods may include more, fewer, or other steps, and the steps may be performed in any suitable order.

What is claimed is:

1. A system for tracking movement of an eye, comprising:

a camera system configured to generate a plurality of images of the eye;

a computer system comprising:

a memory configured to store the plurality of images and store at least one of the images as a reference image; and

one or more processors configured to:

track movement of the eye within a tracking range by comparing a current image of the plurality of images with the reference image, and by determining a rotational movement of the eye from the comparison of the current image and the reference image, the tracking range having a plurality of alert points comprising a tracking boundary point and an intermediate point, the tracking boundary point representing a maximum number of degrees away from a zero point where tracking can be properly performed, the intermediate point located between the zero point and the tracking boundary point; and

determine an orientation of the eye relative to at least one alert point of the tracking range; and

an output device configured to output a range indicator that indicates the orientation of the eye relative to the at least one alert point of the tracking range, the output device comprising a speaker that outputs the range indicator as:

a first sound if the orientation of the eye corresponds to a point between the intermediate point and the tracking boundary point indicating the eye is nearing a tracking boundary beyond which tracking cannot be performed; and

a second sound different from the first sound if the orientation of the eye corresponds to a point beyond the tracking boundary point where tracking cannot be performed.

2. The system of claim **1**, wherein the output device comprises a display that shows the range indicator as a graphical element.

3. The system of claim **2**, wherein the graphical element comprises:

a linear element representing the tracking range, the linear element having at least one alert point element representing the at least one alert point of the tracking range; and

a slider element corresponding to the eye, the position of the slider relative to the alert point element representing the orientation of the eye relative to the at least one alert point of the tracking range.

4. The system of claim **2**, wherein the graphical element comprises:

a linear element representing the tracking range, the linear element having at least one alert point element representing the at least one alert point of the tracking range; and

an arrow element corresponding to the eye, the position where the arrow points relative to the alert point element representing the orientation of the eye relative to the at least one alert point of the tracking range.

5. The system of claim **2**, wherein the graphical element changes continuously from a first color to a second color to indicate a change in the orientation of the eye relative to the at least one alert point of the tracking range.

6. The system of claim **2**, wherein the graphical element changes continuously from a first shape to a second shape to indicate a change in the orientation of the eye relative to the at least one alert point of the tracking range.

7. The system of claim **2**, wherein the graphical element changes continuously from a first size to a second size to indicate a change in the orientation of the eye relative to the at least one alert point of the tracking range.

8. The system of claim **2**, wherein the graphical element shows a first number that continuously changes to a second number to indicate a change in the orientation of the eye relative to the at least one alert point of the tracking range.

9. The system of claim 2, wherein the graphical element shows a first word that changes to a second word to indicate a change in the orientation of the eye relative to the at least one alert point of the tracking range.

10. The system of claim 1, wherein the speaker emits a sound that continuously changes in frequency to indicate a change in the orientation of the eye relative to the at least one alert point of the tracking range.

11. The system of claim 1, wherein the speaker emits a sound that continuously changes in volume to indicate a change in the orientation of the eye relative to the at least one alert point of the tracking range.

12. The system of claim 1, wherein the speaker emits words to indicate a change in the orientation of the eye relative to the at least one alert point of the tracking range.

13. The system of claim 1, wherein the image processing system receives a selection of an alert point of the one or more alert points from user input.

14. The system of claim 1, further comprising a laser system configured to:

receive a notification of the movement of the eye; and

change a laser beam position in response to the notification.

15. The system of claim 1, wherein:

the tracking boundary point is in a range of 10 to 15 degrees.

16. The system of claim 1, wherein:

the intermediate point is one to ten degrees away from the tracking boundary point.

17. The system of claim 1, wherein:

the intermediate point is set by the system.

18. The system of claim 1, wherein:

the intermediate point is set in response to user input.

19. A method for tracking the movement of an eye, comprising:

generating a plurality of images of the eye;

storing the plurality of images and at least one of the images as a reference image; and

tracking movement of the eye within a tracking range by comparing a current image of the plurality of images with the reference image, and by determining a rotational movement of the eye from the comparison of the current image and the reference image, the tracking range having a plurality of alert points comprising a tracking boundary point and an intermediate point, the tracking boundary point representing a maximum number of degrees away from a zero point where tracking can be properly performed, the intermediate point located between the zero point and the tracking boundary point and determining an orientation of the eye relative to at least one alert point of the tracking range; and

outputting a range indicator that indicates the orientation of the eye relative to the at least one alert point of the tracking range, the output device comprising a speaker that outputs the range indicator as:

a first sound if the orientation of the eye corresponds to a point between the intermediate point and the tracking boundary point indicating the eye is nearing a tracking boundary beyond which tracking cannot be performed; and

a second sound different from the first sound if the orientation of the eye corresponds to a point beyond the tracking boundary point where tracking cannot be performed.

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